

**DETERMINATION OF RISK EFFICIENT CROP COMBINATIONS FOR
SMALLHOLDER CONSERVATION FARMERS: AN APPLICATION OF THE
TARGET MOTAD ANALYSIS**

**A Research Report presented to the Department of Agricultural Economics and Extension
Education of the University of Zambia.**

BY

CHRISTINE MTONGA

**In Partial Fulfillment of the Requirements for the Degree of Bachelor of Agricultural
Sciences**

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ACKNOWLEDGEMENTS

First and foremost, I would like to thank the Lord God Almighty for guiding and giving me strength, courage and endurance to face each day and its challenges throughout my stay at the University of Zambia. For this I am eternally grateful.

My sincerest gratitude goes to Ms D.J. Banda my supervisor for her time and effort in guiding me in producing this document. Her efforts, patience and guidance have been instrumental in helping me conclude this report.

Special thanks to Dr. G. Tembo for his time, efforts and guidance as well as the rest of the staff in the Department of Agricultural Economics and Extension Education for having assisted me in one way or the other.

I dedicate this report to my parents Mr J. Mtonga and Mrs. J.M Mtonga who have been such wonderful pillars in my life. I am also grateful for the great help rendered to me by Alefa Banda.

Thank you very much.

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LIST OF ABBREVIATIONS

AMIC	Agricultural Marketing Information Centre
ART	Agricultural Research Trust
CSO	Central Statistical Office
CFU	Conservation farming unit
GAMS	General Algebraic Modeling System
IMCS	Independent management for consultancy services
MACO	Ministry Of Agriculture and Cooperatives
MOTAD	Minimization of Total Absolute Deviations
LP	Linear Programming
Target MOTAD	Target Minimization of Total Absolute Deviations
ZMK	Zambian Kwacha Rebased
FASAZ	Farming Systems Association of Zambia
ZNFU	Zambia National Farmers Union

ABSTRACT

Determination of Risk Efficient Crop Combinations for Smallholder Conservation Farmers: An Application of the Target Motad Analysis

Christine Mtonga
The University of Zambia, 2013

Supervisors:
Ms D.J Banda
Dr. G.Tembo

Conservation farming practicing households like all other small holder farmers in general confront yield and price variability in addition to many other resource constraints. Little is known however about the effects of risks associated with fluctuating crop yields and input or output prices and their effect on the optimal crop enterprise combination. This identifies the need to comprehensively account for risk and its implications for efficient resource allocation, enterprise selection and combination. Thus the study aims to determine risk-efficient enterprise combinations for a representative smallholder conservation farmer in the Southern Province of Zambia who is employing ripping as the main tillage method. The Target MOTAD formulation was used to generate and observe risk efficient farm plans and from the results the different risk levels associated with the plans were observed. The profit maximizing risk and risk efficient enterprises were determined. The risk-efficient farm plans aimed to maximize net returns over variable costs while minimizing the probability of the returns falling below a desired level of income. The results obtained from the model suggested that risk-efficient enterprise combination for a representative smallholder farm household would include maize, groundnuts and soya beans. The other crop under study (cotton) did not enter the model solution. The findings further suggest that for a profit maximizing farm plan 0.663 hectares of maize and 1.737 hectares of Groundnuts should be cultivated. For the risk efficient farm plans, the results suggested allocation of more land to groundnut and soya beans and maize production as the expected shortfall in income (λ) increased from 0 to 25 ZMK below the desired target income of 3,300 ZMK. The choice of a respective risk efficient crop combination or farm plan is dependent on a farm households risk preference. For risk averse farmers the more likely option is the plan with minimum variance (plan 1) while risk preferring households will choose the high income plan which is associated with higher risk plan (5). Therefore, in order to improve the efficiency with which available agricultural resources are allocated among different competing enterprises on a farm, smallholder farmers in southern province should be encouraged through the existing extension system to combine maize, soya beans and groundnuts as this enterprise combination is risk efficient.

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Following independence Zambia's agricultural policy focused squarely on promotion of maize production. Various incentives were put in place such as the fertilizer and input subsidy that resulted in farmers devoting large areas of their land to maize farming. The status quo in the country at this time was 'input intensive ox-plowed maize production'.

The resulting heavy fertilizer application and extensive plowing resulted in declining land quality and productivity. Problems of increased acidity resulting from heavy nitrogen fertilizer application materialized in the central and southern zones. Hence the problem of acidified, eroded and compacted soils motivated the need for farming methods that would reverse the increasingly low productivity and ultimately stimulate increased productivity. Innovation and change was spurred in the Zambian agricultural scene as efforts were underway to find ways of improving the soil structure, organic matter as well as fertility. It was in the late 1980s and early 1990s that actors emerged to try and deal with this problem.

The Zambia National Farmers Union (ZNFU) has played a crucial role in the development and promotion of conservation farming technologies in Zambia. Initial interest began when several commercial farmers in the ZNFU traveled to Australia and the USA in the early and mid-1980's to learn about low-tillage systems. Extensive work and application by Zimbabwean commercial farmers and research at their privately financed Agricultural Research Trust (ART) further stimulated local interest in low-till technologies (Vowles, 1989).

It is from this background that agriculture stakeholders started advocating the use of CF practices by small and medium scale farmers. This message has been spearheaded by organizations such as the department of field services in MACO, the conservation farming unit (CFU) of the Zambian national farmers union (ZNFU), the soil conservation and agro forestry extension

project SCAFE, the Golden Valley Agricultural Trust GART, the cooperative league of the USA (CLUSA) and other NGOs.

The conservation farming (CF) system they advocate involves:

- Dry-season land preparation using minimum tillage methods (either ox-drawn rip lines or hand-hoe basins laid out in a precise grid of 15,850 basins per hectare);
- No burning but rather retention of crop residue from the prior harvest;
- Planting and input application in fixed planting stations; and • nitrogen-fixing crop rotations.

CF, as applied in Zambia, generally involves a package of several key practices: dry-season land preparation using minimum tillage systems; crop residue retention; seeding and input application in fixed planting stations; and nitrogen-fixing crop rotation (Haggblade and Tembo 2003a and 2003b). Research in the region and elsewhere has indicated that those who adopt CF methods have the potential to reduce their costs, increase their yields, reduce food security risks, minimize the chances of crop failures in drought years, increase their profits, and in time improve the fertility of their land (Kabwe and Donovan, 2005).

1.2 Problem Statement

A number of studies in Zambia have been carried out that have dealt comprehensively with conservation farming matters and have addressed various issues such as development and diffusion, adoption and impact, yield gain evaluation, benefits and problems of ripping and financial profitability (Haggblade and Tembo 2003; Kabwe, Donovan and Samazaka 2006; Kabamba and Muimba-Kankolongo 2009; Haggblade, Kabwe and Plerhoples 2011; Kabwe, Donovan and Samazaka 2007). However, the literature available did not adequately discuss the risk element of conservation farming technology in Zambia.

Accounting for the risk factor in agriculture is important as it affects farmers behavior which is generally described to be risk-averse (Dillion and Scandizzo, 1978). Disregarding farmer's behavior in the face of risk on the other hand can result in "overestimation of output levels of risky enterprises and overly specialized cropping patterns" (Hazel, 1982). Also since farmers are faced with scarce resources it is very important for them to allocate them in a way that gives them returns that satisfy their expectations relative to their risk preference.

Many studies conducted outside Zambia focusing on risk and efficient resource allocations have mainly focused on conventional farming tillage methods. Therefore this paper aims to fill the knowledge gap of literature by carrying out a risk study that focusing on conservation farming and analyzing the impact of this risk under the CF system on crop enterprise combinations for the small holder farmer.

1.3 Objectives

1.3.1 General Objectives

Therefore the general objective of this study was to determine the risk efficient crop combination for a conservation farmer. Specific objectives include the following:

1.3.2 Specific Objectives

- To determine how the farming technology of conservation farming affected the optimal crop enterprise selection.
- To determine the profit maximizing combination that minimized risk.

1.4 Rationale

Farmers face a variety of risk in agriculture which includes price risk and production risks. Risk is uncertainty that affects an individual's welfare and is often associated with adversity and loss. In the case of small holder farmers this loss could involve yield losses or poor sales form price variability.

Risk management involves choosing among the alternatives to reduce the effects of risks. For small holder farmers practicing conservation farming this entails reducing the inherent risk they face in agriculture by selection of crop combinations that have the ability to reduce the risk they face. Therefore modeling resource allocation subject to risk is important as it helps in risk management decisions on small holder farms.

Also understanding the impact of risk is important because in Zambia most of the small holder farmers are employed in the primary agricultural sector, this implies that they derive most of their income from farming activities therefore for farming families that find the need to change their farming technology to conservation farming there is need for more information on the possible risk involved in this move as they can no longer rely on past knowledge or life long experience to allocate resources efficiently.

It has also been observed that Zambian smallholder agriculture has become more diversified over the past decade with maize, cassava, groundnuts, cotton, horticultural crops, and animal products all becoming important sources of cash revenue as well as production for home consumption except, of course, cotton (Zulu *et al.*2007), but farmers also face constraints in acquiring the inputs they need for these enterprises such as fertilizer, agrochemicals, seed etc with the prevalent price and yield variation (Isik, 2002) hence the importance of efficient resource allocation in risk minimizing crop combinations to help farmers maximize the use of these scarce inputs and reduce chances of loss. This study uses survey data collected under the CFU to look at resource allocation behaviors among farmers and suggest risk efficient allocations these of resources. Available literature suggests that most farmers are risk-averse and that risk aversion tends to be more common among small farmers (Dillion and Scandizzo, 1978).

It is stressed by Hazell (1982) that neglect of risk-averse behaviour of farmers can result into overestimation of the output levels of risky enterprises and overly specialized cropping patterns. Also given that small farmers are risk averse in agricultural planning models, the results generated in empirical analysis may be of little use either in direct decision-making or in policy analysis (Brink and McCarla, 1978, and Boisvert and McCarla, 1990).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

From the analysis of literature it was observed that many studies have been carried out in agriculture that use the Target MOTAD as a means of analyzing risk. Risk is an important aspect of any venture and understanding it is very important. This is why over the years various methods of risk analysis have also been employed and techniques of analysis have evolved. Conservation agriculture is a fairly new technology compared to the conventional practice of agriculture hence in comparison fewer studies have been carried out in this area. This section reviews relevant literature on conservation farming and risk and also includes key definitions, types and sources of risk, risk modeling techniques, conservation agriculture studies as well as risk modeling studies

2.2 Definition of Key Terms

According to FAO¹ conservation agriculture is a concept for resource saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Conservation agriculture is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt the biological processes. From this definition a conclusion can be drawn that conservation agriculture is not a technology but a range of technologies premised on application of one or more of the 3 main conservation agriculture principles (IIRR & ACT 2005).

Conservation farming can be defined as any system or practice which aims to conserve soil and water by using surface cover (mulch) to minimize runoff and erosion and improve the conditions

¹ FAO conservation agriculture website: <http://www.fao.org/ag/ca/index.html>

for plant establishment and growth. It involves planting crops and pastures directly into land which is protected by a mulch using minimum or non-tillage techniques.

2.3 Types and Sources of Risk

Production risk in agriculture is characterized by high variability of production outcomes. Since farmers are not able to predict with certainty the amount of output that the production process will yield due to external factors like weather, pests and diseases unlike other enterprises. Production risk may also result from adverse event during harvesting or threshing. Price or market risk is a result of input and output price volatility. This may be because of high volatility of prices of agricultural commodities. Output price volatility originates from both exogenous and endogenous market shocks. Segmented agricultural markets will be influenced mainly by local supply and demand conditions. Financial and credit risk involves how businesses finance their activities.

Many agricultural production cycles stretch over long periods of time and farmers must anticipate expenses that they will only be able to recuperate once the product is marketed. This leads to potential cash flow problems exacerbated by lack of credit and the high cost of borrowing. Institutional risk is generated by unexpected changes in regulations that influence farmers' activities. Changes in regulations, financial services, level of price or income support payments and subsidies can significantly alter the profitability of farming activities. Technology risk is as a result of adoption of new technologies in modernizing agriculture such as in introduction of genetically modified crops causes an increase in producer liability risk. Personal risk comes about as agricultural households are exposed to personal risks affecting the life and the well being of people who work on the farm, as also asset risks from floods, cyclones and droughts and possible damage or theft of production equipment or any other farming assets.

2.4 Conservation Agriculture Studies

Several studies have been conducted on conservation agriculture that has focused on different aspects and these studies have employed various evaluation methods. Some of these studies have

been qualitative while others quantitative and the analysis and conclusions drawn have provided relevant information to the body of knowledge on conservation farming. Some of the studies done are reviewed and from this review it is evident that little work has been done on conservation farming that models the risk that is involved in Zambia.

An example of a risk modeling study was conducted in Virginia on a peanut cotton farm that focused on analysis of risk of adopting conservation practices on the farms and focused on evaluation of cost of reducing pesticide, nitrogen, phosphorous and sediment loss for representative risk neutral and risk averse farmers (Peng 1997).

Another analysis using the Target MOTAD analysis of crop and livestock was done in Jefferson county Florida. The analysis incorporated the potential complementarities among beef and cattle enterprises. The target MOTAD framework was used to account for risk in a decision framework. (Zimet and Spreen, 1986).

A series of case studies on conservation farming have been carried out in Tanzania, Ghana, Uganda, Kenya and Zambia. These studies have been to verify and document the status and effect of pilot initiatives on conservation agriculture with a focus on sub Saharan Africa.

Here a qualitative study that synthesizes experiences and results obtained by applying and using conservation agriculture principles and technologies in a specific region in past or ongoing efforts and projects. The focus is on conservation agriculture techniques and processes, on the key issues and lessons learned, as well as on shortcomings and successes. Sheto, Richard; Owenya, Merietha, eds. 2007 conservation as practiced in Tanzania: case studies.

2.5 Whole Farm Planning and Risk

The whole farm planning problem has been identified as a simultaneous determination of those enterprises to adopt, the method of production to employ in each enterprise, and the amount of resources to allocate to each enterprise. In the absence of risk, the whole farm planning problem

may be solved as a linear programming problem (Anderson, 1980). However, risk inherently exists in agriculture and this entails accounting for it in the farm planning process.

2.6 Techniques of Risk Programming

Several techniques in risk programming have developed over the recent years and have dressed risk in decision making. In agriculture most risk programming applications have employed the mean-variance or MOTAD decision making criteria. Here we discuss these techniques and also include quadratic programming and the Target MOTAD.

The basic idea of EV model is that the method applies mathematical concept of variance as a measure of risk. This is justified under conditions of normally distributed expected income and farmer's utility function that could be expressed by negative exponential function. In such a case it could be assumed that farmers make decisions on the basis of expected income (average value) and variance (standard deviation) as a measure of risk (Hardarke *et al* 2007). From a mathematical point of view the problem could be addressed by quadratic programming. The proper estimation of farmers' risk attitude (coefficient of risk aversion) is crucial to find the optimal production plan or to locate farmers' decision margins in expected value-variance (E, V) space. The E-V function or space is the risk-efficient frontier which gives the minimal level of variance associated with given levels of expected income or the maximum levels of expected income for given levels of variability. The frontier is estimated by maximizing expected income subject to given levels of variance or minimizing the variance subject to given levels of expected income (Fauer, 1983, Ejimakor, 1989, McCarl and Spreen, 1997).

A deviation of the E-V model was developed by Hazell (1971). This model uses the mean absolute deviation as a measure of risk as opposed to using mean square deviation. Since the objective function in the model is the minimization of the total absolute deviations. Hazell called it the MOTAD model. Introduction of the above measure of risk into a programming model requires the use of only negative deviations from mean net income. The model depicts tradeoffs between expected income and the absolute deviation of income (McCarl and Spreen, 1997). The model can be solved by parametric linear programming to obtain the efficient E-V set of farm

plans. Once these plans have been obtained the variance of their income can be calculated using the MAD estimator. A notable problem with the E-V models is the assumptions it has about the shape of the utility function and the distribution of expected income. It assumes a quadratic utility function when the utility function is unknown. Also it assumes income is normally distributed and can completely be described by mean and variance. The actual distribution may be skewed hence these restrictions bring about the need for less restrictive alternatives. One such alternative introduced is that of stochastic dominance.

The concept of second degree stochastic dominance was introduced by Josef Hadar and William Russell as a means of predicting a decision maker's choice between given pairs of risky alternatives without having any knowledge of a decision makers utility function except that it displays risk aversion. Second degree stochastic dominance does this by giving necessary and sufficient conditions on a pair of risky prospects for one to be preferred or indifferent to the other by all risk averse decision makers².

Proposed by Loren W. Tauer is an alternative mathematical programming model that is computationally efficient and generates solutions meeting the second degree stochastic dominance criteria. The model has two attributes of risk and return. Return is measured as the sum of the expected returns of the activities multiplies by their individual activity level. Risk is measured as the expected sum of the negative deviations of the solution results from a target-return level. Risk is varied parametrically so that a risk-return frontier is traced out and SDD efficient results can be obtained³.

Tauer (1983) also noted that the Target MOTAD model has a linear objective function and linear constraints, thus it can be solved with a linear programming algorithm. The basic objective of the model is to analyze the maximum expected return from the production activity subject to a given minimum level of risk identified with a predetermined target level of return. The target income is the minimum income necessary to cover the variable costs of farmers including credit repayment, and to meet his family's living costs each year (Khanal et al, 2008).

² Meyer, J. (1977). "Second Degree Stochastic Dominance with Respect to a Function". *International Economic Review*, vol.18,(No.2),477-487

³ Tauer, L.W.(1983). "Target MOTAD". *American journal of Agricultural Economics*, vol.65, (No.3), 606-610

2.7 Conceptual Framework

The neoclassical principal of profit maximization assumes that firms aim to maximize profit. If this assumption holds for small holder farmers then under producer theory, a small holder farmer producing to maximize profit will produce at the point where marginal value product will equal the marginal cost of production in the absence of resource constraints.

$VMP_{ij} = C_j$ (1)

Where VMP is the value marginal value product of input j in the production of crop i and C_j is the unit cost of input j. Equation (1) requires that each input used in the production of each crop should be allocated in such a way that the value of the marginal products is the same in all uses. But farm production is not a riskless activity and it is because of this that expected utility is used as a decision theory, it is thus assumed that the farmer tries to maximize expected utility in the face of risk. The utility to be maximized is often hypothesized to be a function of both expected profit and the variance of profit. Such an expected utility function is represented as

$E(U) = E(Z) - bV(Z)$ (2)

Where $E(.)$ is the expectations operator, U is the utility function, Z is profit, b is the risk aversion coefficient and V is the variance of Z . Equation 2 shows that expected profit is reduced by a risk premium defined by the last expression of the equation.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter will review the methodology that was employed for this study. The analytical framework which was used to analyze the data and obtain results that satisfy the objectives is reviewed and information is also provided on the data collected, its sources and the way in which it was analyzed.

3.2 Analytical Framework

In this study the target MOTAD framework is used to obtain the profit maximizing crop combination that takes into account the risk factor inherent in agriculture. The model proposes an alternative mathematical programming model that is computationally efficient and generates solutions meeting the second degree stochastic dominance (SSD) test and is a modification of Hazell's (1971) MOTAD model. The concept of second degree stochastic dominance enables us to predict a decision maker's choice between a pair of risky alternatives without having any knowledge of the decision maker's utility function except that it displays risk aversion. Risk here is measured as the expected sum of negative deviations of solution results from the target level, the return is measured as the sum of the expected returns multiplied by their individual activity level hence this model is a two attribute risk and return model.

The Target MOTAD model can thus be used to determine the optimal crop enterprise combination that maximizes total return over variable cost while minimizing the probability of obtaining a return below a desired target level hence satisfying the safety-first rule (Tauer, 1983; Todd et al, 2003). The model is mathematically stated as follows;

$$\text{Maximize } EINC = \sum_t \bar{C}_j X_j \quad (1)$$

s.t.

$$\sum_j a_{ij} x_j \leq b_i \quad (2)$$

$$\sum_j c_{jt}x_j + Z_t^- \geq \text{TGINC}, \forall t \quad (3)$$

$$\sum_t p_t Z_t^- = \lambda \quad (4)$$

$$x_j, Z_t^- \geq 0, \forall j, t \text{ Non-negativity conditions} \quad (5)$$

Where \bar{c}_j is expected return from activity j , x_j is level of activity j , a_{ij} , technical requirement of activity j for resource or constraint i , b_i level of resource or constraint i , c_{jt} is income from activity j in state of nature t , TGINC is target income, p_t is probability of a state of nature, λ is allowable average deviation below TGINC, and Z_t^- is value of any deviation in income below the target in state of nature or observation t , given by;

$$Z_t^- = \sum_{j=1}^n (c_{jt} - \bar{c}_j) x_j. \quad (6)$$

Equation (1) maximizes expected income, while equation (2) fulfills the resource constraints. In equation (3), the variable Z_t^- is non zero if the t^{th} income result falls below TGINC. If that revenue is less than the target, TGINC, the difference is transferred to equation (4) through variable Z_t^- . Equation (4) sums the negative deviation after weighing them by their probability of occurring, p_t . Thus; the Target MOTAD model has two parameters relating to risk (TGINC and λ) which must be specified. These, in turn, can be parameterized to yield different risk solutions.

3.3 Data Collection and Analysis

Secondary data was used and was collected from different institutions. This included survey data on conservation farming from IMCS and CFU, input and output prices were collected from MACO' agricultural marketing and information centre AMIC, sample enterprise budgets for various crops were obtained from MACO and input- output technical coefficients from a world bank publication on Zambia (Seigal & Alwang 2005). This data was then used to calculate gross margins for each crop by first calculating average input and output prices.

The output prices were multiplied by the calculated average crop yields to obtain the revenues for each crop. Costs for each crop were determined using the data on enterprise budgets and these costs were subtracted from the revenues to get the respective crop gross margins. The

correct syntax was then typed in the general algebraic modeling system (GAMS) software for the final analysis. The crops considered in this study include cotton, maize groundnuts and soya beans based on how widely they are grown in southern province. Area allocation was used to determine this as MACO (2011) data revealed that 315,655 ha was allocated to maize, 76,721 ha was allocated to groundnuts, 25,377 ha was allocated to cotton and 9,724 ha was allocated to soya beans. The final results of the target MOTAD implemented in the GAMS software were aggregated using EXCEL.

3.4 Study Assumptions

No definite measure of cash at hand was available at the time of the study therefore it was assumed that recorded farmer average total revenue from all the crops could be used as a lower bound proxy for available working capital. It was assumed that the farm families practice low level management and only use family labor on their farms and on average 450 man days estimated to be available for all the crops. Finally it was assumed that 2.3 ha of land were available for each household in the southern province (CSO 2011) and target level income was assumed to be k 3,300.

CHAPTER FOUR

STUDY FINDINGS AND DISCUSSION

4.1 Introduction

The study findings are presented in this chapter. First risk programming target MOTAD results are presented, the coefficients of variation in returns are then also presented to show the risk levels associated with each farm plan including shadow prices for land and labor across the farm plans. Finally the Target MOTAD frontier is presented to depict the relationship between the expected income and the variance.

4.2 Low Risk Profit Maximizing Farm Plans

With the specified target income at 3,300 ZMK, risk efficient farm plans were generated by applying the target MOTAD technique and the results are as shown below (Table 1). The target income specified was assumed to be the subsistence level of income for a smallholder farm household and risk was measured as the expected short fall, λ , from the target level of income.

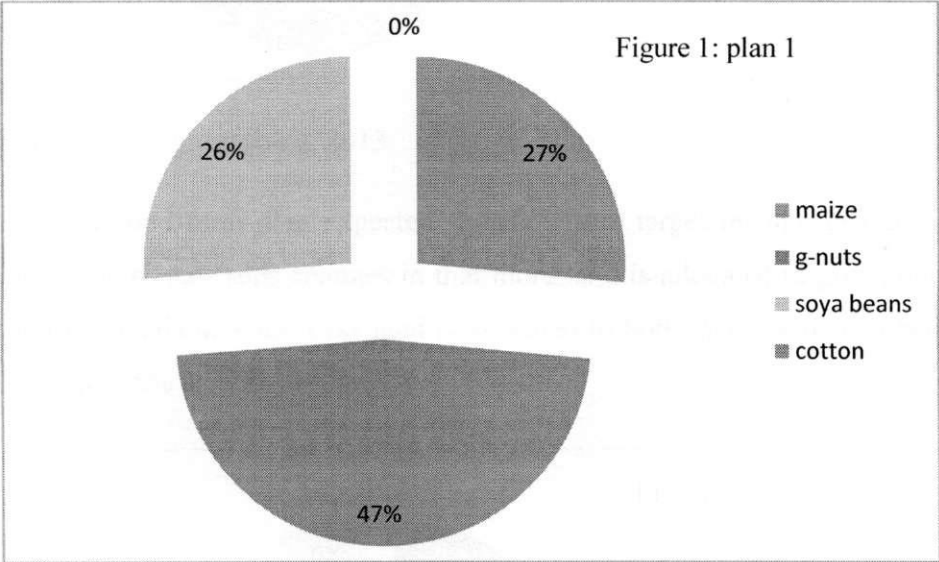
Table 1: Target MOTAD Risk Efficient Farm Plans

		Target MOTAD farm plans				
Characteristics	Units	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
Target Income	ZMK	3,300	3,300	3,300	3,300	3,300
Expected short fall (λ)	ZMK	0	10	15	20	25
Expected Income	ZMK	3455.015	3627.543	3713.808	3800.074	3879.246
Variance in Income (billions) ZMK		0.7	3.5	5.7	7.4	7.6
<u>Crop mix:</u>						
Maize	Hectares	0.635	0.565	0.53	0.495	0.663
Groundnuts	Hectares	1.137	1.464	1.627	1.791	1.737
Soya beans	Hectares	0.628	0.371	0.242	0.114	0
Cotton	Hectares	-	-	-	-	-
Total Land utilized	Hectares	2.4	2.4	2.4	2.4	2.4
Total labor	Hours	353.4	377.5	393.3	409.2	409.3

Source: Authors calculations, 2013

As λ was increased from zero, solutions that represented the optimal farm plan allocation were obtained. For each change in λ , the corresponding expected income and optimal solutions were obtained and recorded for the target level of income considered as shown in Table 1. Expected income ranged from 3879.246 ZMK when negative income deviations were ignored to 3455.015 ZMK when negative income deviations were not permitted i.e. $\lambda=0$.

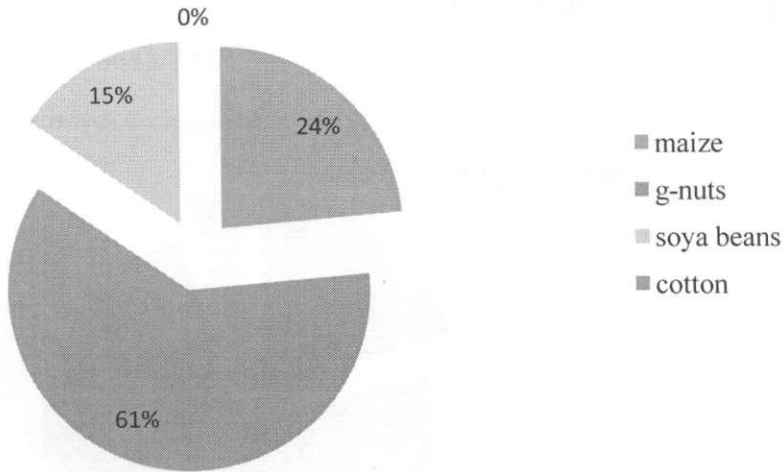
As λ was increased from zero, the solutions generated varied with different combinations of farm plans. Generally it was observed that as λ increased the area allocation to maize reduced an exception was plan 5 where it increased. The area allocated to groundnuts increased across the farm plans and only declined in farm plan 5 and it was found that cotton was not included in all five farm plans. This could have been due to the low cotton prices that were experience in the years under consideration resulting in low allocation of land to the crop and ultimately low revenue hence it was not considered as a risk efficient crop. The individual farm plans can graphically be presented below;



Source: Authors analysis, 2013

The first farm plan has the lowest variance of 0.7 and $\lambda=0$ which shows that it is the most risk efficient farm plan. It advises that 1.137 ha of land should be allocated to groundnuts, 0.635 ha should be allocated to maize and 0.628 ha to soya beans. This means for a low risk farm plan one must allocate 47% of their land to groundnuts as it is a high income and low cost crop. 27% must be allocated to maize as it is produced for subsistence as well as for revenue, 26% should be allocated to soya beans and 0% to cotton production.

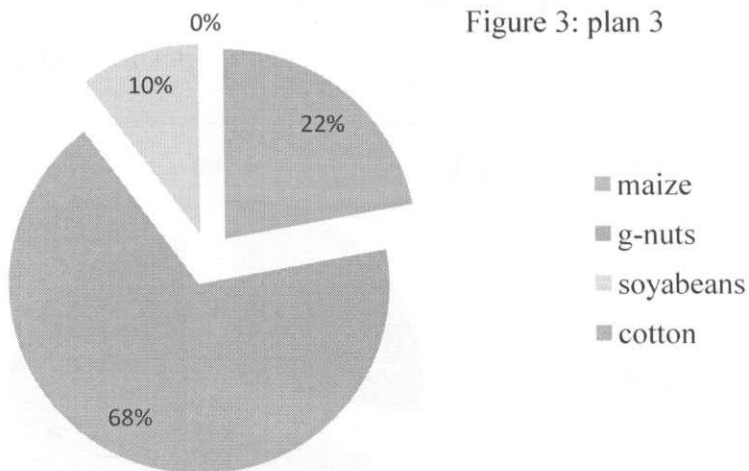
Figure 2: plan 2



Source: Authors analysis, 2013

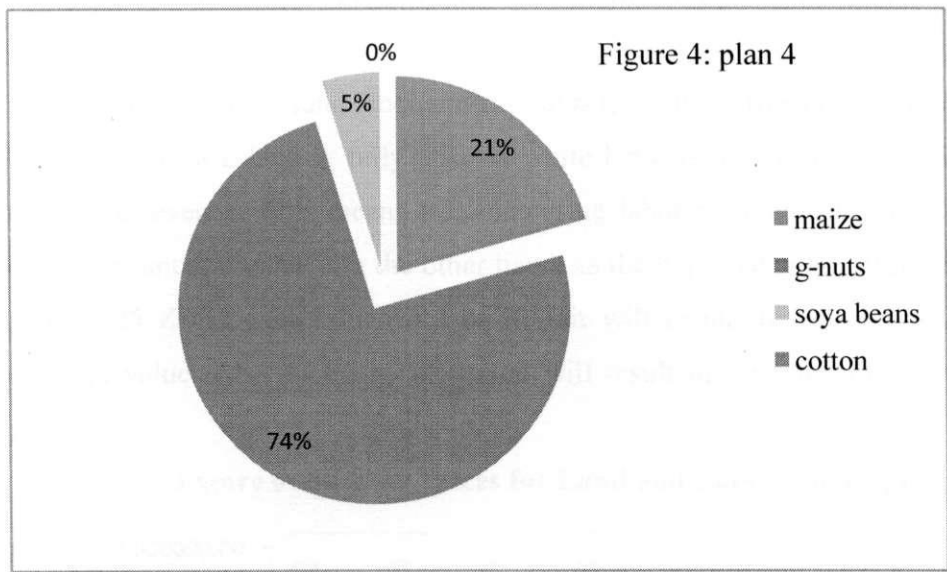
In the second farm plan expected shortfall from target income increases to 10 ZMK, and the allocation to the crops changes in that more land is allocated to groundnuts and it takes 61% of the total available land. Less land is allocated to both maize and soya beans hence they take up 24% and 15% area respectively.

Figure 3: plan 3



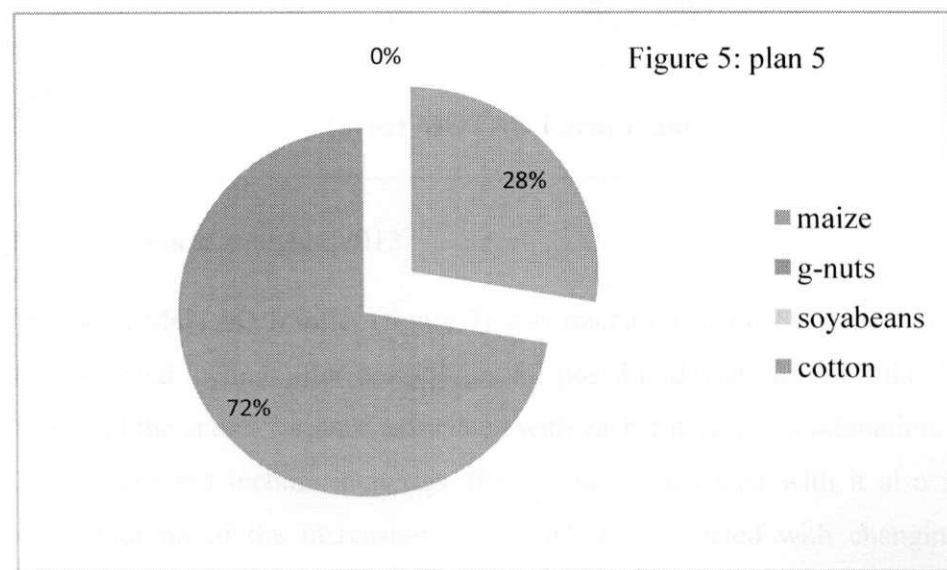
Source: Authors analysis, 2013

Plan 3 suggests further reduced allocation of land to Maize and Soya beans cultivation, but an increase in the cultivation of Groundnuts with no cultivation of cotton at the higher expected shortfall (λ) value of 15 ZMK.



Source: Authors analysis, 2013

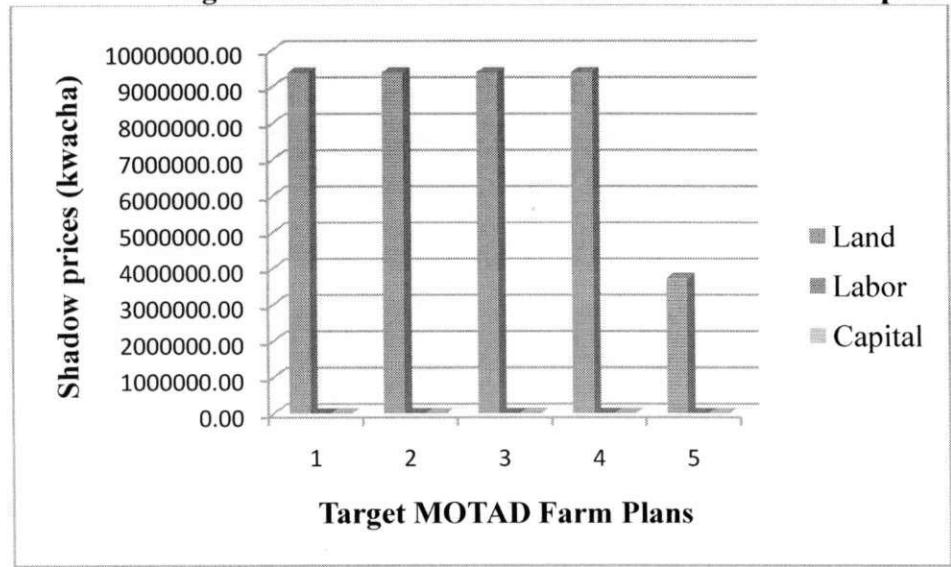
Plan 4 suggests reduced maize and soya beans cultivation to 20% and 5% respectively and a continued increase in allocation of land to groundnuts at the increased expected shortfall (λ) of 20 ZMK and variance of 7.4.



Plan 5 which has the highest risk associated with it at a variance of 7.6 and expected shortfall in income of 25 suggests allocation of land to Groundnuts and Maize production only. Both cotton and Soya beans are not included in the farm plan and this combination is the profit maximizing enterprise combination and is recommended for the farmers with high risk taking attitude.

The shadow prices for land labor and capital across all the five farm plans are presented in figure below. As shown, land is fully utilized while labor is in excess and capital is fully utilized to maximize revenue. This means that increasing labor by 1 unit will result in no change in the objective function value. On the other hand, as the expected shortfall increases from zero all the way to 25 ZMK, increasing land by 1 unit will result in reduced increase in the objective function value. Also a change in capital will result in a whole different combination of farm plans.

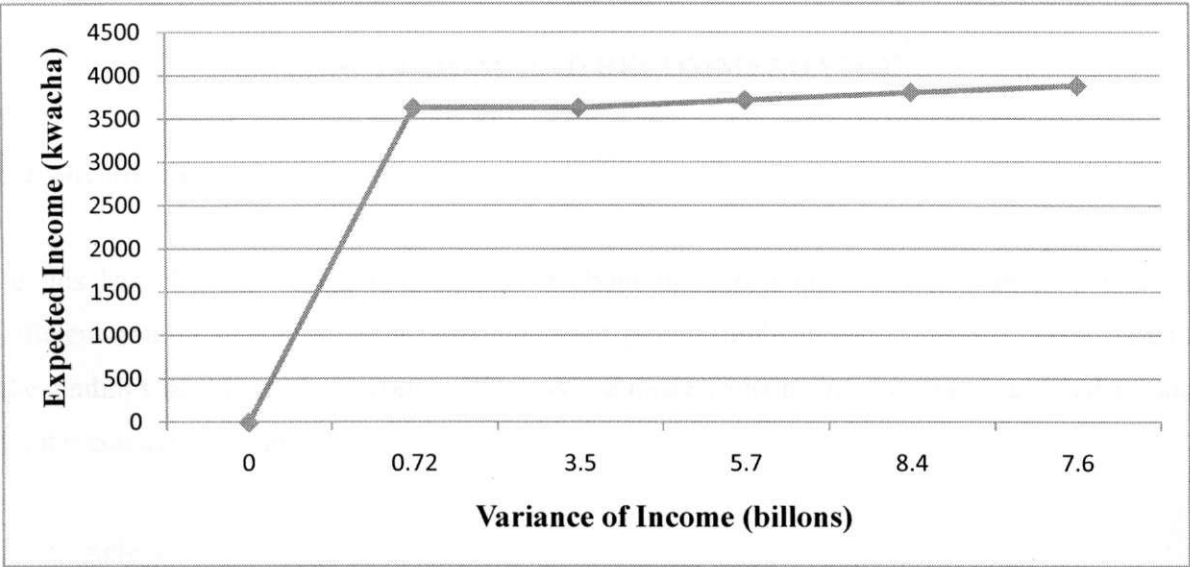
Figure 6: Shadow Prices for Land and Labor and Capital in ZMK



Source: Authors analysis, 2013

A Target MOTAD frontier (figure 7) was traced out below. It depicts the relationship between the expected income after considering all possible deviations from the desirable target income level and the actual variance associated with each enterprise combination. As it can be observed, as the expected income increases, the variance associated with it also increases. This is as a representation of the increasing risk which is associated with changing from lower income enterprises to higher income enterprises.

Figure 7: Target MOTAD Frontier



Source: Authors analysis, 2013

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In this last chapter, conclusions are made about the profit maximizing farm plan and risk-efficient enterprise combination; also important policy implications are drawn. Then based on the findings of this study, recommendations are made to help improve the livelihood of small holder conservation farmers.

5.2 Conclusions

The results obtained from the target MOTAD model suggests that the risk-efficient enterprise combination for a representative smallholder conservation farming household will include the following crops; Maize, Groundnuts and Soya beans. This is so when the target income is 3,300 ZMK and the expected shortfall (λ) ranges between 0 and 25 ZMK. With an expected shortfall (λ) in income of 25 ZMK and more, efficient farm plans will only comprise of two enterprises specifically, Groundnuts and maize hence as risk levels increase the more profitable crops or crops most likely to reduce risk of production are maize and groundnuts.

The amount of land allocated to Maize and Soya beans should be reduced as risk becomes increasingly important. In this way there will be a positive change in the objective function value. Of the two resources land and labor, land is a binding constraint while labor is in excess. This means increasing the area of land under cultivation by one hectare will result in a positive increase in the objective function value i.e. expected income.

A positive relationship exists between expected income level and the associated variances evident from the Target MOTAD frontier. Therefore, the higher expected income the higher the risk levels associated with it. The choice of a respective risk efficient farm plan will however, depend on farm households risk preference. Risk averse households will most likely trade

expected income for low variance which is a case for Plan 1 as opposed to risk preferring households who will most likely choose farm plans with high expected income and are associated with larger variance in income for instance, Plan 5, while risk neutral households will most likely select farm plans in between the two extremes i.e. Plan 1 and Plan 5.

5.3 Recommendations

Based on the study findings I would recommend that small holder conservation farmers be advised through CF agencies to increase area allocation to groundnuts as it is a profitable crop as well as a legume that promotes soil fertility. Also diversity in crop production must be advised to change the mentality of the farmers from only depending on maize as a staple crop so that they can realize that other crops are profitable and can improve their livelihoods

Secondly programme implementing agencies must be encouraged to use the target MOTAD as a tool for modeling farm plans so as to determine alternative enterprise combinations which may be presented to the farmers to allow them to decide which best suits them based on their risk preference. Also these agencies can choose an optimal plan to promote which best fits a particular region or choose farm plans that are best suited for different groups based on social aspects or land endowment.

Finally the extension workers promoting the adoption of the practice of conservation farming must be trained on informing the farmers and their households on the different farm plan combinations and the implications of adopting them. This means informing them of the risk associated with each farm plan in a manner that they can fully comprehend.

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ANEXES

Annex 1: Output Prices per kg for the respective Crops in ZMK

Crops	2009	2010	2011
Maize	1,728.98	1,300.00	875.41
Ground nuts	5,192.71	4,156.10	5,300.00
Soya beans	3,200.00	3,500.00	3,800.00
Cotton	1,220.00	1,250.00	3,600.00

Source: AMIC commodity prices, 1994-2012

Annex 2: Summary of Crop Production Characteristics and Labor Requirements in Labor Days/Ha activities for Southern Province

Production Characteristics					Labor Requirements in Labor Days/Ha							
	Technology	Variety	Management	Fertilizer use	Land-pre	Planting	Weeding	Fertilizer	Guard	Harvest	P-Harvest	T
	OX	Hybrid	Low	Yes	17	5.2	27	7	11	27.2	25	1
ndnuts	OX	Local	Low	No	8	8	24	0	12	48	90	
a	OX	Hybrid	High	No	11	2	20	2	22	50	4	

ce: Siegel and Alwang, (2005)